Electromagnetic Fields

Coulomb's Law

$$F = \frac{1}{4 \cdot \pi \cdot \epsilon_0 \cdot \epsilon_r} \cdot \frac{Q_1 \cdot Q_2}{r^2}$$

Electrical Field

$$\overrightarrow{E} = \frac{\overrightarrow{F}}{Q}$$

$$E = \frac{U}{d}$$

Point Charge

$$E = \frac{1}{4 \cdot \pi \cdot \epsilon_0 \cdot \epsilon_r} \cdot \frac{Q}{r^2}$$

Gauss Law For Electric Fields

$$\Phi_E = \oint \overrightarrow{E} \cdot d\overrightarrow{A} = \frac{Q_{\text{net}}}{\epsilon_0 \epsilon_r}$$

Electrical Potential

$$U = \frac{w}{q}, \quad W = q \cdot U$$

Electrical Voltage

$$U_{PQ} = U_P - U_Q$$

$$W_{PQ} = q \cdot U_{PQ}$$

Capacitor

$$Q = C \cdot U$$

$$C = \frac{\epsilon_r \cdot \epsilon_0 \cdot A}{d} \quad \text{(plate capacitor)}$$

$$W = \frac{1}{2} \cdot C \cdot U^2 \quad \text{(energy storage)}$$

Current

$$I = \frac{Q}{t}, \quad i(t) = \frac{dq}{dt}$$

Ohm's Law

$$U = R \cdot I$$

Resistance in material

$$R = \rho \cdot \frac{L}{A}$$

$$R_T = R_0(1 + \alpha(T - T_0))$$

Voltage Sharing and Current Sharing

$$U_2 = \frac{R_2}{R_1 + R_2} \cdot E$$

$$I_1 = \frac{R_2}{R_1 + R_2} \cdot I_0$$

Faraday's Induction Law

$$U_{\text{ind}} = -\frac{d\Phi_m}{dt}$$

Coil

$$U = L \cdot \frac{di}{dt}$$

$$L = \frac{\mu_0 \cdot \mu_r \cdot N^2 \cdot A}{l}$$

$$W = \frac{1}{2} \cdot L \cdot I^2$$

Effect

$$P = U \cdot I = R \cdot I^2 = \frac{U^2}{R}$$

$$P = \frac{W}{t}$$

Magnetic Flux

$$\Phi = B \cdot A \cdot \cos\theta$$

Where θ is the angle between the normal of $\overrightarrow{\boldsymbol{A}}$ and $\overrightarrow{\boldsymbol{B}}$.

Charge in Magnetic Fields

$$F = q(\overrightarrow{v} \times \overrightarrow{B})$$

For a straight conductor:

$$F = I(\overrightarrow{l} \times \overrightarrow{B})$$

Magnetic Fields Created by Live Conductors

Long straight conductor:

$$B = \frac{\mu_r \cdot \mu_0 \cdot I}{2 \cdot \pi \cdot r}$$

Coil:

$$B = \frac{\mu_r \cdot \mu_0 \cdot N \cdot I}{l}$$

Toroid:

$$B = \frac{\mu_0 \cdot \mu_r \cdot N \cdot I}{2 \cdot \pi \cdot R}$$

Alternating Voltage, Alternating Current

$$u(t) = \hat{u} \cdot \sin(\omega \cdot t)$$

$$i(t) = \hat{i} \cdot \sin(\omega \cdot t + \varphi)$$

$$\omega = 2 \cdot \pi \cdot f \qquad f = \frac{1}{T}$$

$$U = u_{\text{eff}} = \frac{\hat{u}}{\sqrt{2}} \qquad I = i_{\text{eff}} = \frac{\hat{i}}{\sqrt{2}}$$

$$P = U \cdot I \cdot \cos(\varphi)$$

Where φ is the angle phase angle between voltage and current.

Addition of Sinus Waves

$$\sum_{i=1}^{N} A_i \cdot \sin(\omega \cdot t + \alpha_i) = A \cdot \sin(\omega \cdot t + \alpha)$$

Where $A = \sqrt{X^2 + Y^2}$ and $\tan\alpha = \frac{Y}{X}$, where X and Y is given by:

$$X = \sum_{i=1}^{N} A_i \cdot \cos\alpha_i, \quad Y = \sum_{i=1}^{N} A_i \cdot \sin\alpha_i$$

RC-Circuit

Capacitor Discharge:

$$u(t) = U_0 \cdot e^{-\frac{t}{\tau}}$$

Capacitor charging

$$u(t) = U_0 \cdot \left(1 - e^{-\frac{t}{\tau}}\right)$$

Time Constant:

$$\tau = R \cdot C$$

Impedance

Kapacitive:

$$Z_C = X_C = \frac{1}{\omega \cdot C}$$

Inductive:

$$Z_L = X_L = \omega \cdot L$$

$$Z = \frac{U}{I}$$

$$Z_{\text{totseries}} = \sqrt{R^2 + (\omega L - 1/\omega C)^2}$$

$$\tan\varphi = \frac{\omega L - 1/\omega C}{R}$$

Average Effect:

$$P_{\text{eff}} = U_{\text{eff}} \cdot I_{\text{eff}} \cdot \cos\varphi$$

Resonance:

$$\omega_0 = \frac{1}{\sqrt{L \cdot C}}$$

$$f_0 = \frac{1}{2 \cdot \pi \cdot \sqrt{L \cdot C}}$$

Transformer

$$\frac{U_1}{U_2} = \frac{N_1}{N_2} \qquad \frac{I_2}{I_1} = \frac{N_1}{N_2}$$

Impedance Transform:

$$Z_2 = Z_1 \left(\frac{N_2}{N_1}\right)^2$$